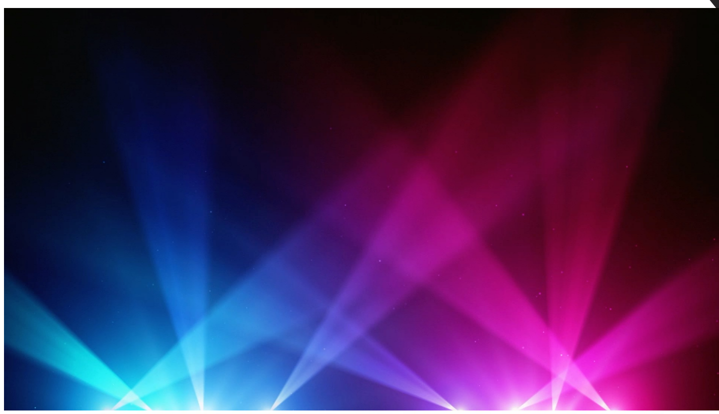


DISCO: Deep Ice & Sea Calibration Observer

Cartsen Rott, Segev BenZvi, Mike DuVernois, Kenneth Golden, Ben Jones, & Christoph Toennis

Proposed DISCO instrument

Calibration unit for large volume water and ice Cherenkov detectors

Exploratory unit for detailed sea ice properties

Proposed in the US under the NSF MRI (Major Research Infrastructure) ~$1M

Looking for collaborators & applications more broadly

Support from IceCube, KM3NeT, Baikal, P-ONE, TRIDENT, plus the sea ice community

Potential applications to other detectors

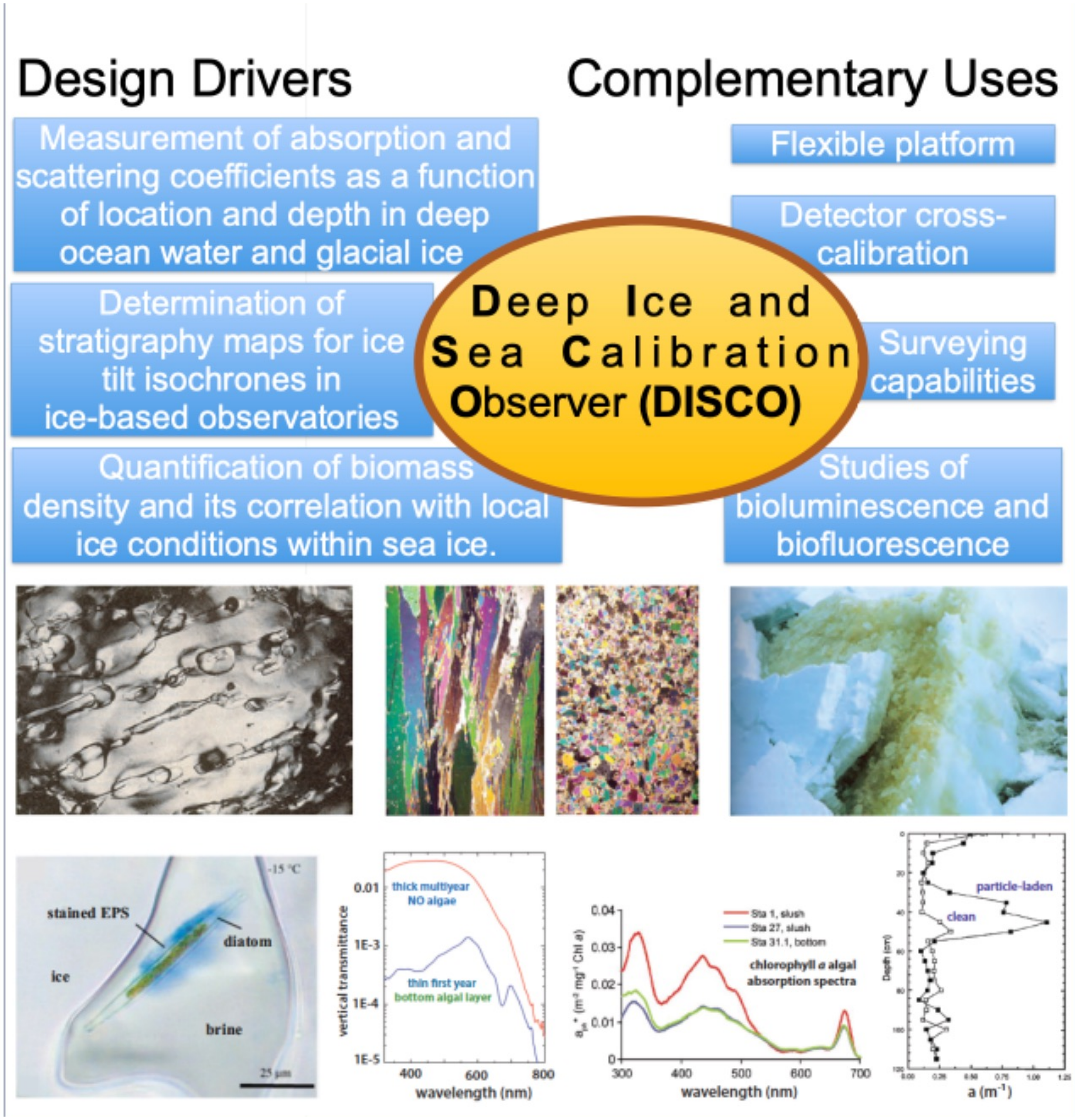
Measurements include absorption & scattering by position, orientation, & frequency

A new era in astroparticle physics has begun with the discovery of high-energy astrophysical neutrinos, a coincidence observation of energetic neutrinos and γ-rays from a blazer [1], evidence for neutrino emission from NGC1068 [2] and from the Milky Way by the IceCube Observatory. Further progress in this emerging field is fueled by multiple large volume neutrino detectors now operating, all with funded efforts for expansions: IceCube [3] with its Upgrade [4] at the geographic South Pole, the Mediterranean ANTARES with KM3NeT [5], and Lake BAIKAL [6] with the GVD extension. Proposed large detectors include P-ONE [7] in the Pacific, IceCube-Gen2 [8], and TRIDENT.

Polar sea ice forms one of the key components of Earth's climate system that is most impacted by planetary warming. As a material, it is a multiscale, polycrystalline composite of pure ice with brine, air, and particulate inclusions. Moreover, the sea ice interior hosts extensive communities of microbial extremophiles like algae, that serve as a critical lynch-pin in the marine food web. Improving projections of the health of polar ecosystems in the face of precipitous sea ice losses, requires advances in understanding how algal biomass distributions are correlated with local ice conditions. Wide-ranging surveys of these internal properties over large expanses of sea ice with portable instruments are not presently practical, with much present information derived from ice core studies. An instrument to conduct large-area surveys of biomass density as a function of depth and microstructural features would enable significant progress in understanding algal dynamics in the rapidly changing polar marine environment. The optical properties of sea water have been subject to multiple studies (ex. [14]). Efforts to determine the transport of light through ocean water

Views of natural ice

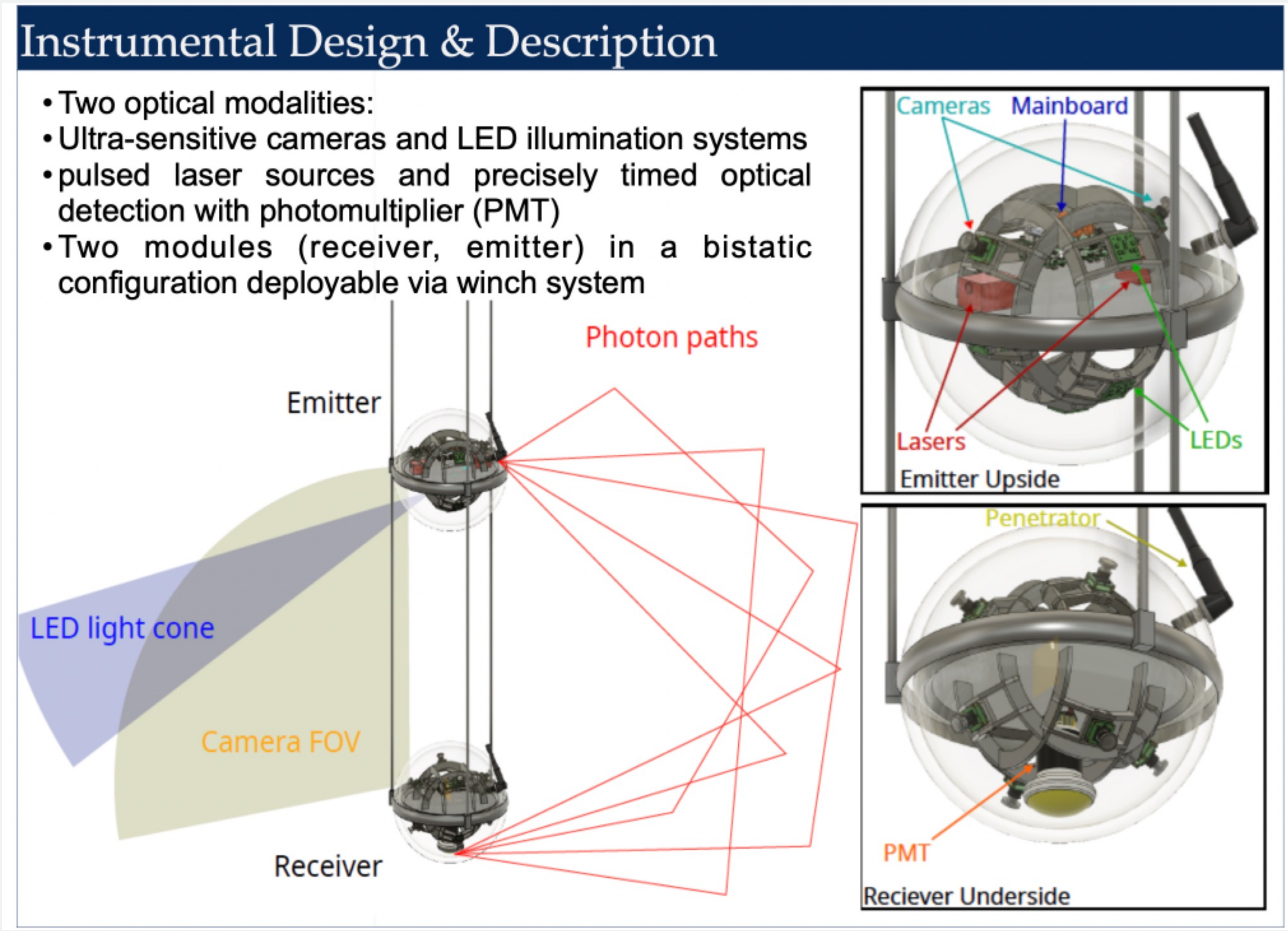
Brine inclusions



Stratigraphic structure plus tilt plus fabric orientation

Sea ice melting is accelerated by both organic & inorganic inclusions

Here setup in a more hole-based geometry…



Common clock on both modules

Lightweight surface DAQ with on module data storage

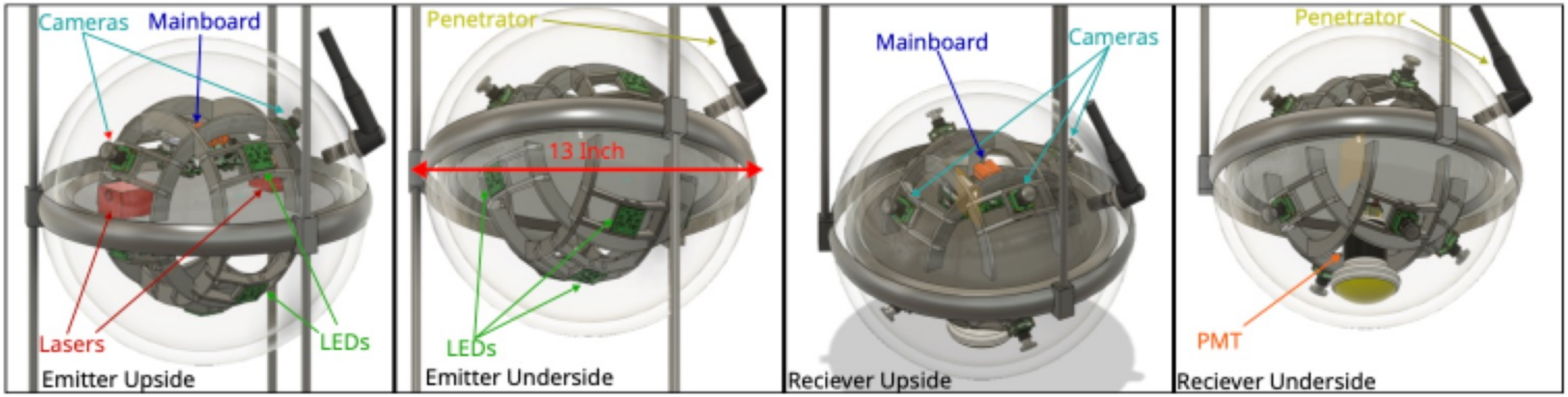


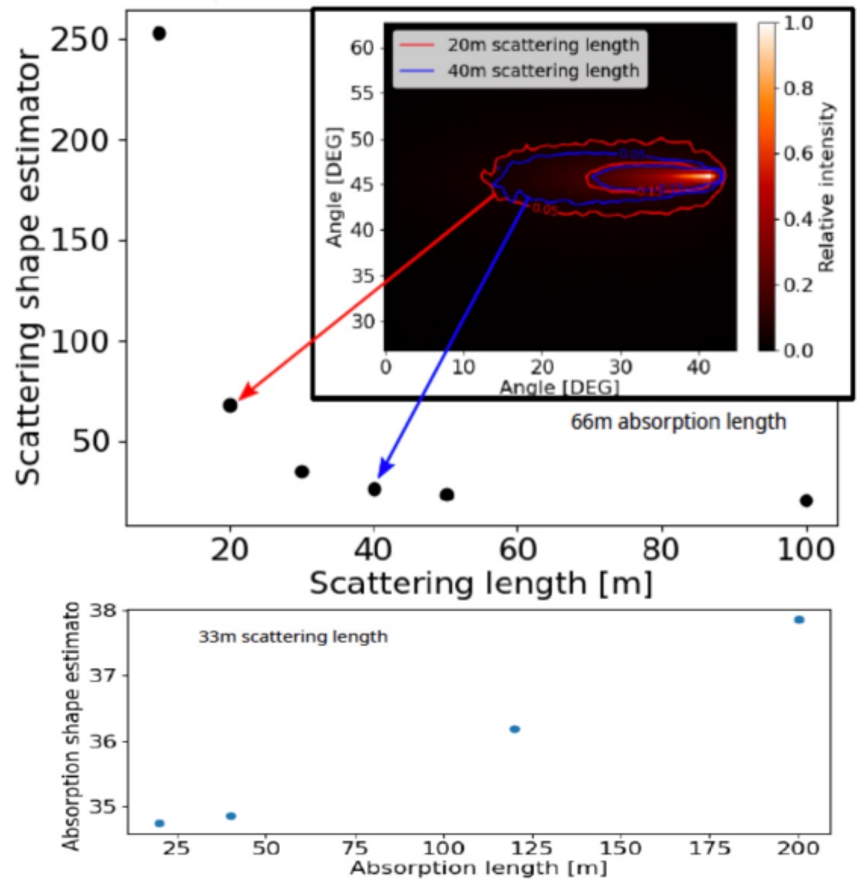
Figure 2: A 3D model of the basic design concept for the emitter and receiver module.

Modules built from some IceCube Upgrade common components

LEDs & Lasers in emitter unit. PMT and PD in receiver unit. Both modules have cameras.

Similar to the intended IceCube Upgrade camera measurements

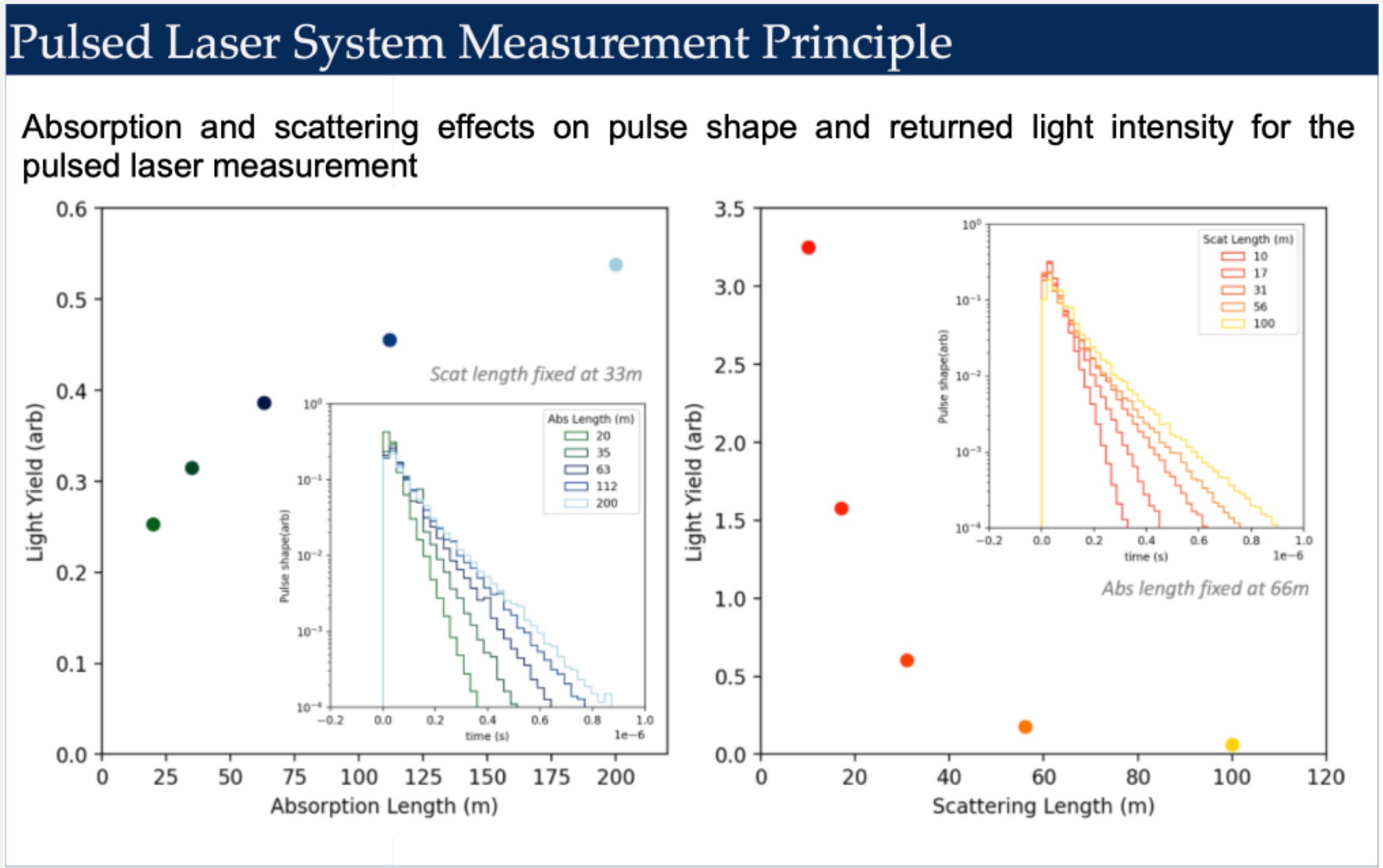
Camera Measurement Principle



Expected camera image using a 2° beam at 3 m nodule separation. Obtained optical medium parameters based on preliminary image analysis.

Offline image analysis

Similar in principle to the ice dust loggers employed in the past



Position & orientation sensors onboard

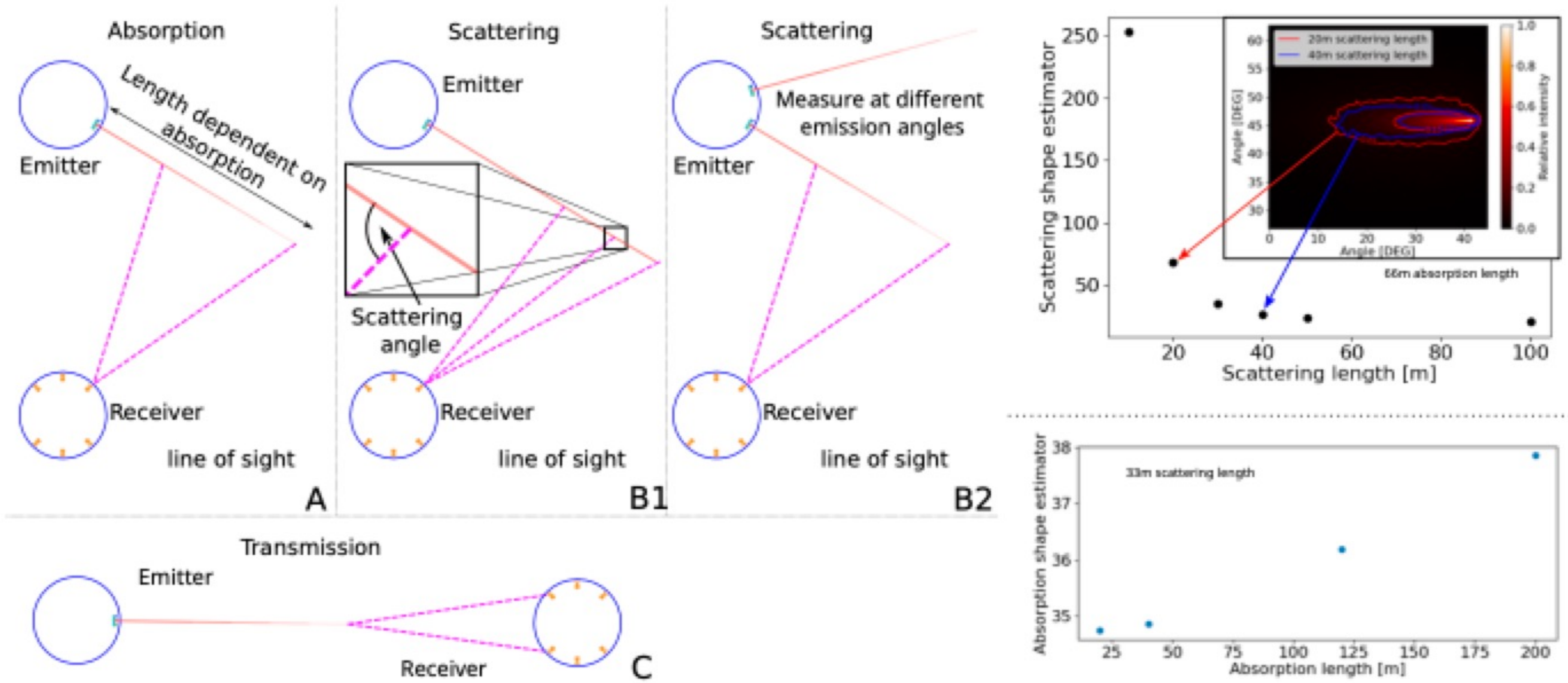


Figure 3: Left: DISCO configurations for A: Absorption; B1: Scattering function B2: Anisotropy; C: Sea ice transmission measurement, Right: Expected camera image using a 2° beam at 3 m distance and obtained optical medium parameters based on image.

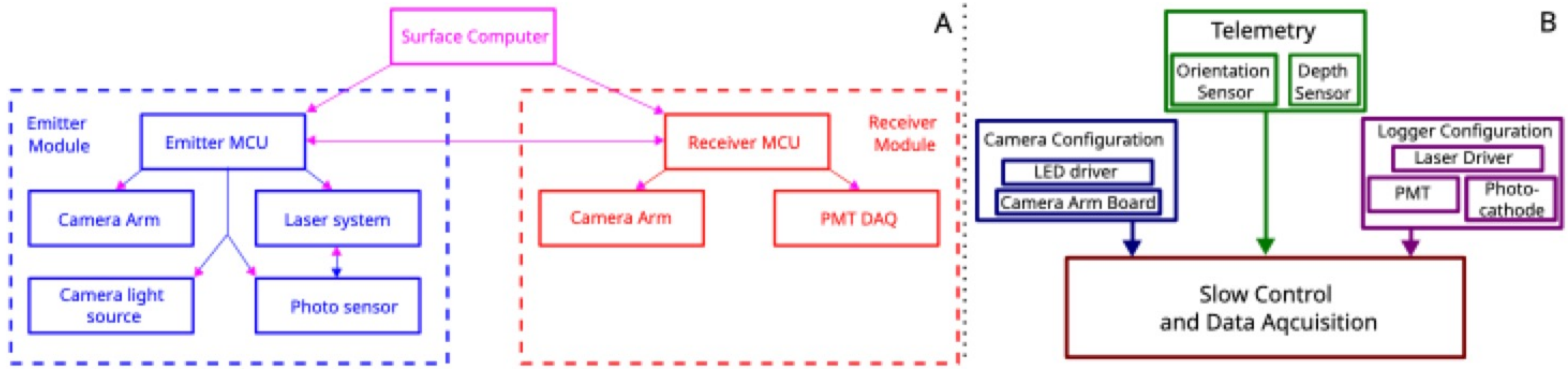


Figure 7: A: Diagram of the hardware components used in the modules; B: Control flow of the software.

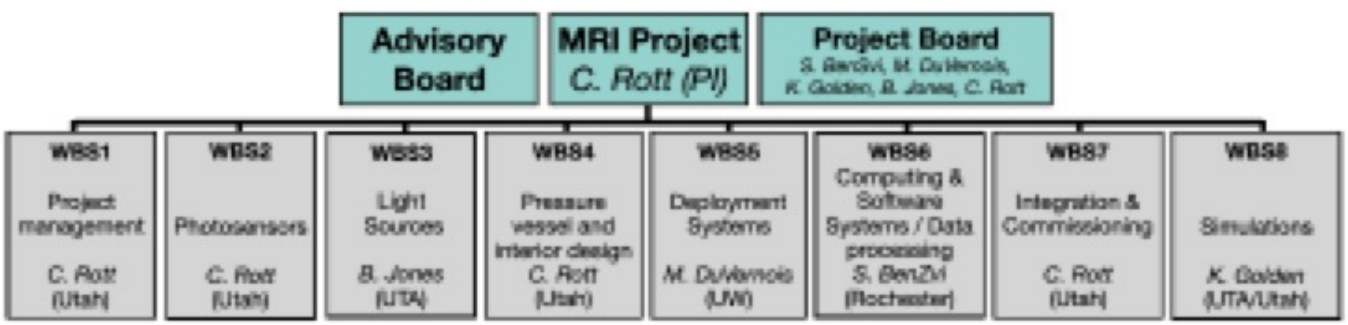


Figure 8: WBS and management structure

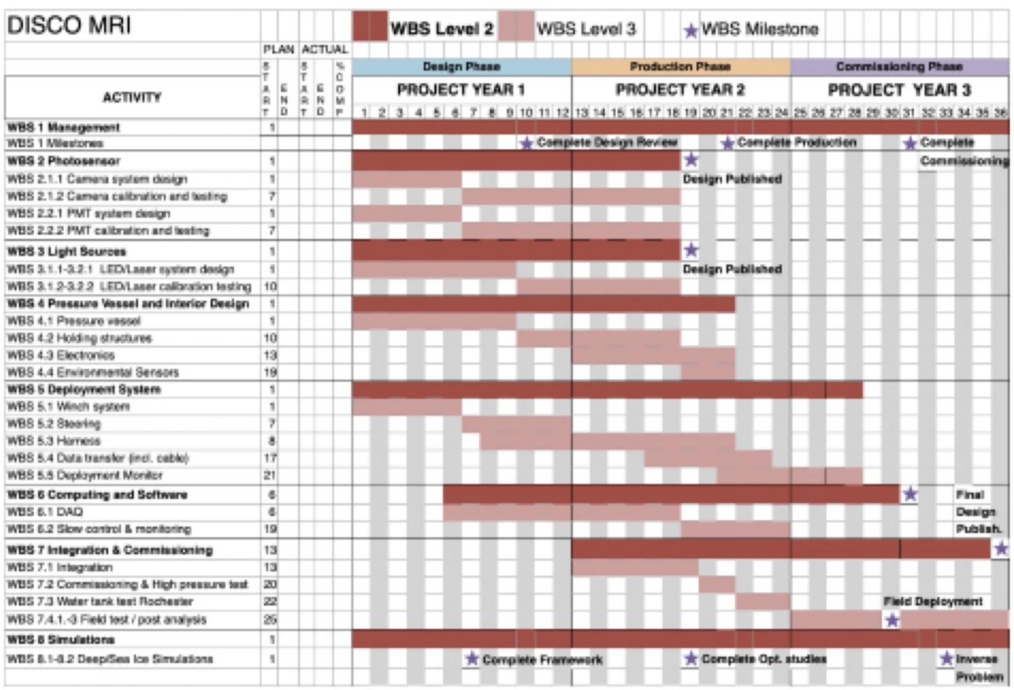


Figure 10: Schedule for this project broken down according to Month, Year, and WBS.

Ignore the details…

Too late now for IceCube Upgrade in 2025-2026

But quick once funded, about two years to functional hardware

Targeting water detectors first, sea ice, and finally IceCube-Gen2

Conclusions

- We propose a multipurpose optical instrument for neutrino detector calibration and sea ice observations
- A modular and expansible platform design allows for specialized tasks
- Basic conceptual design is presented, and further sensitivity and optimization studies are ongoing, to be followed by the construction of a prototype instrument
- A design workshop will be held this Fall at the University of Utah. Interested parties are invited to participate

For sea ice measurements, could install spectrophotometer for organic/inorganic absorption determination/separation

Modules would support additional instruments as desired

Nominal operating mode is a "deployment" but longer-term monitoring also possible for ocean

Not funded in NSF MRI 2023, we are open to other options for collaboration or helping out specific other calibration efforts

Workshop at Utah part of series starting with Upgrade camera goals

This instrument came out of the last (Feb 2023) Utah camera workshop

Backups

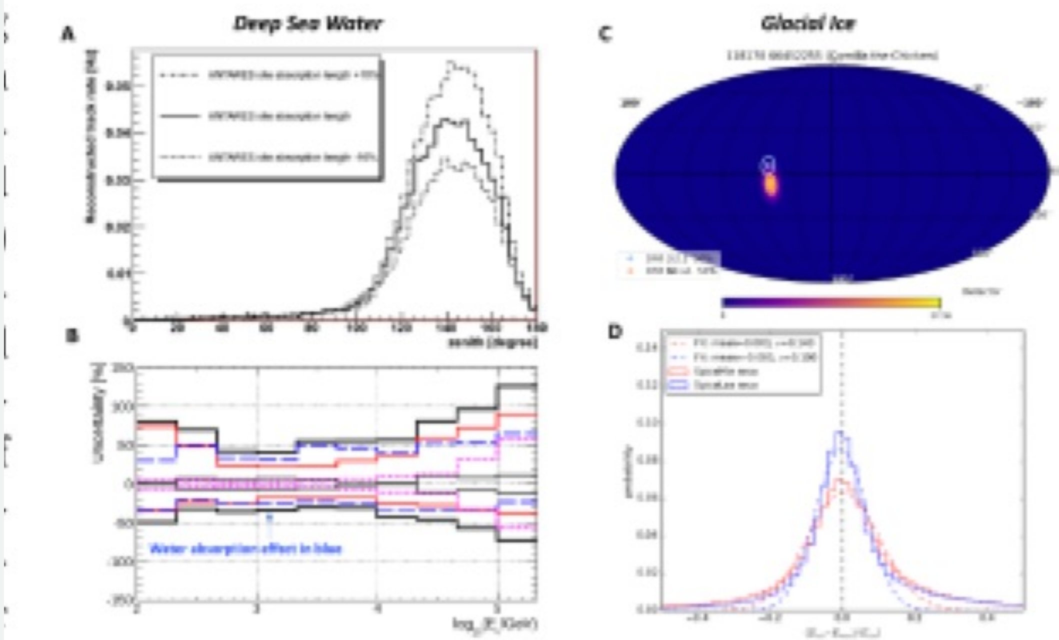


Figure 2: Effects of water and ice property uncertainty on neutrino telescopes. From ANTARES (deep sea water): A) effect of water absorption coefficient on muon rate, and B) energy-dependent systematic uncertainty on detection rate in a modern analysis. From IceCube (glacial ice), C) effect of ice model update between two modern iterations on cascade angular and D) energy reconstruction.

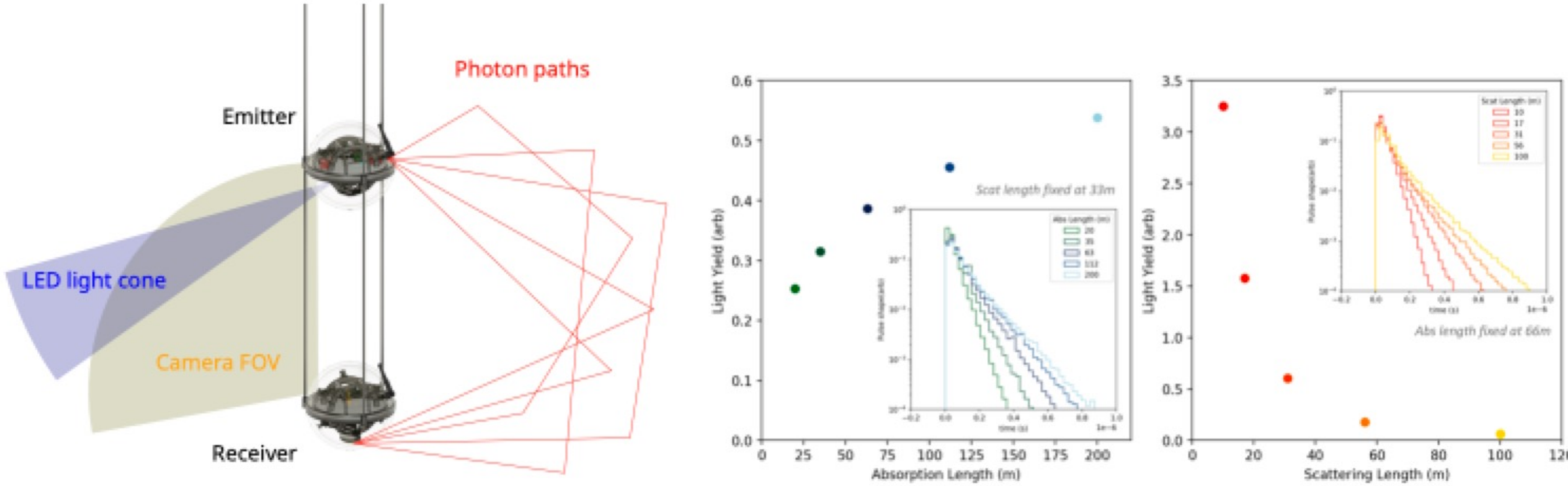


Figure 1: Left: Concept of DISCO. LED light cone observed by cameras (left side) and Laser observed by the PMT logging system (right side). Right: Absorption and scattering effects on pulse shape and returned light intensity for the pulsed laser measurement.

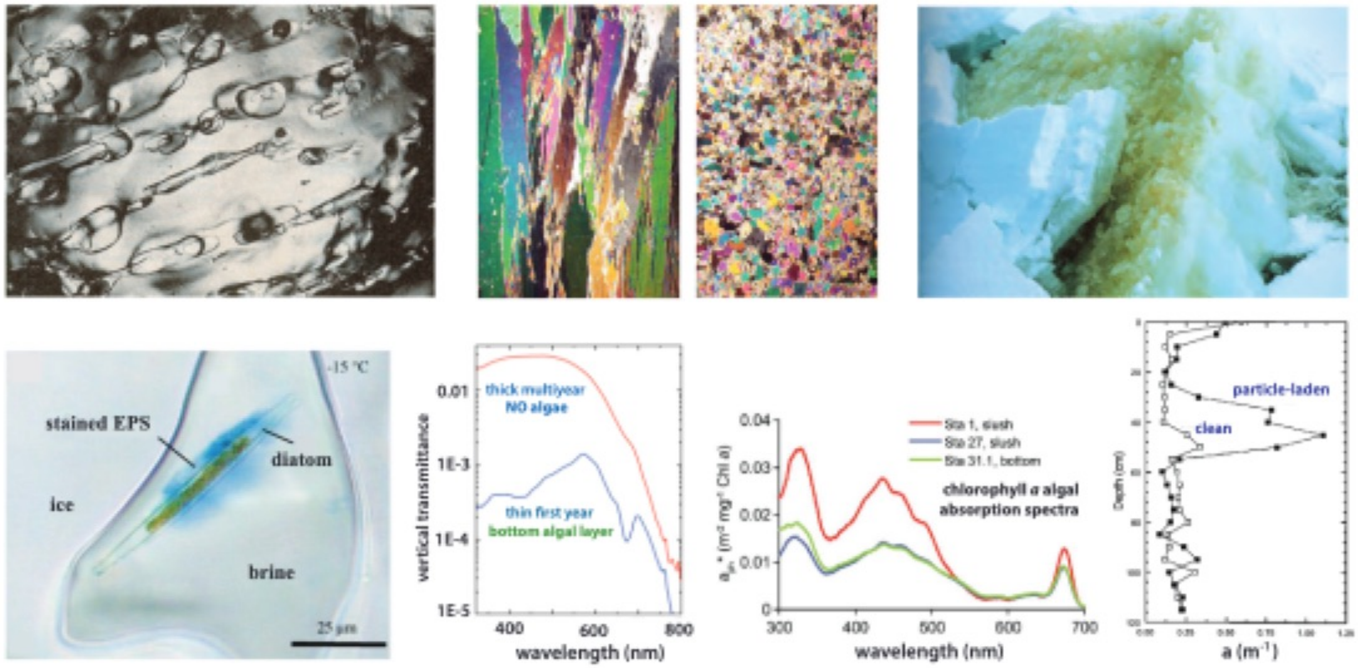


Figure 3: Sea ice microstructure and algal absorption spectra. Top row (left to right): The volume fraction and connectivity of the mm-scale brine inclusions [17] depend strongly on temperature; cm-scale thin section of columnar sea ice grown under quiescent conditions, under polarized light; granular ice grown under turbulent or wavy conditions (J.-L. Tison); gap layer in Antarctic sea ice with algae (C. Haas). Bottom row (left to right): diatom in brine and secreted extracellular polymeric substance, dyed blue (C. Krembs); comparison of vertical transmission spectra for ice (200 cm) with no algae (red), vs. ice (108 cm) with an algal bottom layer (D. Perovich); algal absorption spectra for high biomass sites in Antarctica [18]; comparison of vertical profiles of absorption coefficients at 440 nm for "clean" ice vs. a floe with a particle-laden layer [19].

2023 Workshop on Camera-systems and image analysis for neutrino detector calibration, glaciology and deep sea exploration

A two-day workshop on the use of camera systems

Workshop dates are the 2nd and 3rd of February 2023

Hosted by the Department of Physics and Astronomy at the University of Utah